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ELEMENT MATERIAL EXPOSURE EXPERIMENT BY EFFU

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INTRODUCTION

The National Space Development Agency of Japan (NASDA) is planning to perform an "Element Material Exposure Experiment" using the Exposed Facility Flyer Unit (EFFU).

This paper presents an initial design of experiments proposed for this project by our company. The EFFU is installed on the Space Flyer Unit (SFU) as a partial model of the Space Station JEM exposed facility. The SFU is scheduled to be launched by H-II rocket in January or February of 1994, then various tests will be performed for three months, on orbit of 500 km altitude, and it will be retrieved by the U.S. Space Shuttle and returned to the ground. The mission sequence is shown in Figure 1.

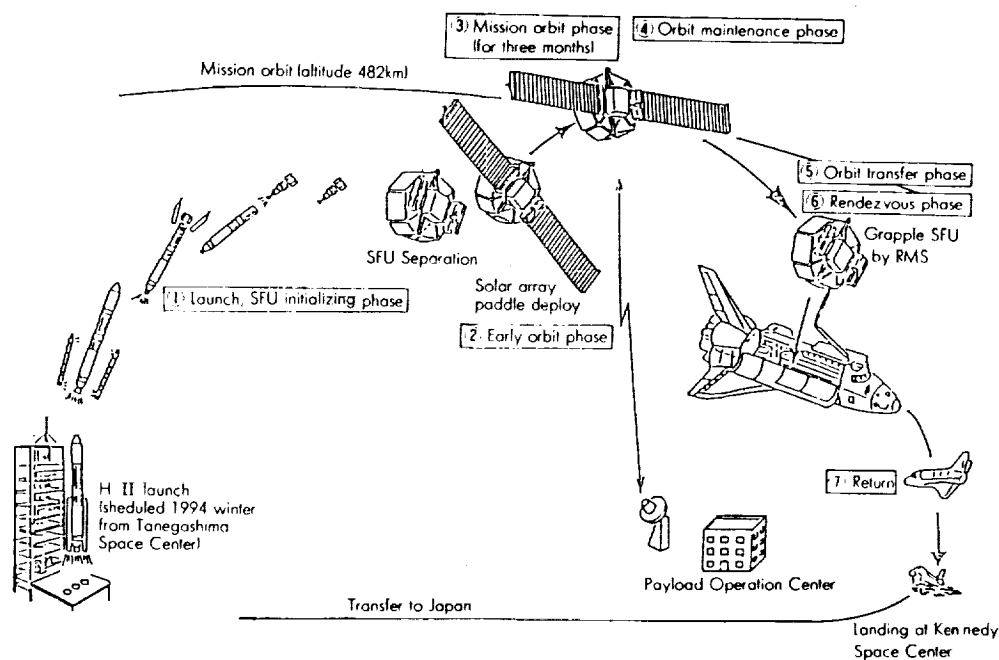


Figure 1. Flight operation profile of SFU.

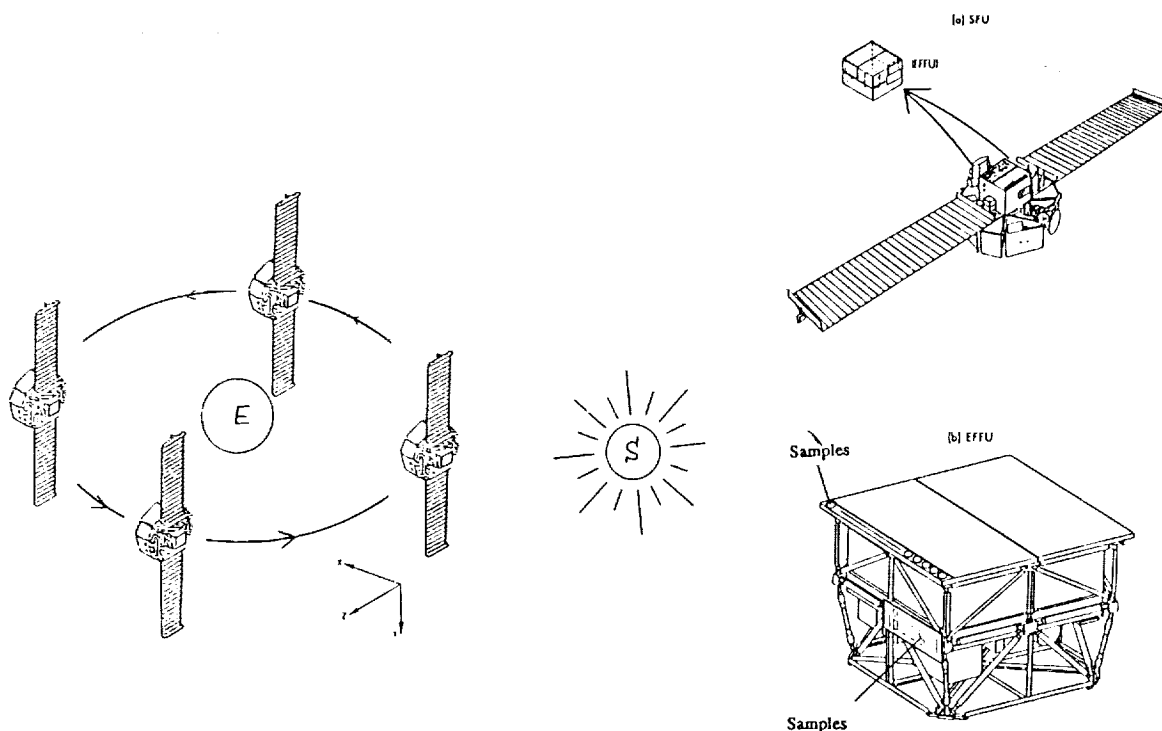
PURPOSE AND MERIT OF THE EXPERIMENT

Two main purposes of the experiments are as follows:

- a. Confirmation of strength of element materials to be used in Japanese Experiment Module (JEM) of the Space Station Freedom against AO and/or UV in LEO.
- b. Research and Development for future projects.

In the LEO environment, the major factors contributing to the degradation of materials are AO and UV. In some cases, those synergistic effects must be more important.

SFU's basic attitude is "Solar pointing" (see Figure 2(a)). In this attitude, one surface faces the sun at all times and receives abundant irradiation of ultraviolet rays. To the others, no direct solar irradiation is given. As for AO irradiation, the plural panels receive atomic oxygen flux in the same manner (in sine curve). By using this advantage, three different irradiations are being applied; for example, AO, UV, and AO+UV.



(a). Solar pointing mode (Basic attitude).

(b). Location of installation.

Figure 2. Installation and the flight.

FIVE MAIN EXPERIMENTS

Five main experiments proposed by IHI are shown in Table 1. Thermal control coatings and films are our concern because they are often used as the materials exposed to space and measurements of LEO component degradation urgently required. They include anodized, indium-tin-oxide and silicon-dioxide coatings and Teflons. Three themes are proposed for them (Themes 1, 2 and 4).

The only active monitoring performed by the exposure experiments at this time is temperature monitoring; this is done by one thermistor placed at the center of the sample panel prepared for this experiment. We have planned unique environment monitoring equipment to find out both the AO and UV flux (Theme 5).

As a research and development theme, "Comparison of damage among different direction arrangements of graphite crystals" is projected (Theme 3).

Purpose and background for each experiment theme are described in detail later.

Table I. Five Main Experiments

- | | |
|----|---|
| 1. | Comparison of durability characteristics among different anodizing processes. |
| 2. | Growth of erosion from coating defects. |
| 3. | Comparison of damage among different direction arrangements of graphite crystals. |
| 4. | Effects of UV, AO and their synergism on different types of fluorocarbon. |
| 5. | SFU orbit environment monitoring by Kapton. |

COMPARISON OF DURABILITY CHARACTERISTICS AMONG DIFFERENT ANODIZING PROCESSES

The Purpose of this experiment is to evaluate the strength of different anodized coatings under the LEO environment. The objects are coated with chromic, sulphuric and oxalic acid.

Aluminum anodizing is known to be stable against AO attack. Therefore, anodized aluminum foil used as the outer cover of multi-layered insulation can be very effective for long-life spacecrafts.

Different anodizing processes produce different surface optical properties. We expect that there also exists some differences of durability against AO/UV among those three types of coating.

Each type of coating has these characteristics as follows:

1. Chromic acid anodizing can give various α/ϵ by changing voltage and processing time (See Figure 3(a)).
2. Sulphuric acid anodizing provides low α adaptable as a radiator of spacecrafts.
3. Oxalic acid anodizing is said to be unaffected by UV and solar absorptance (α) is rather stable.

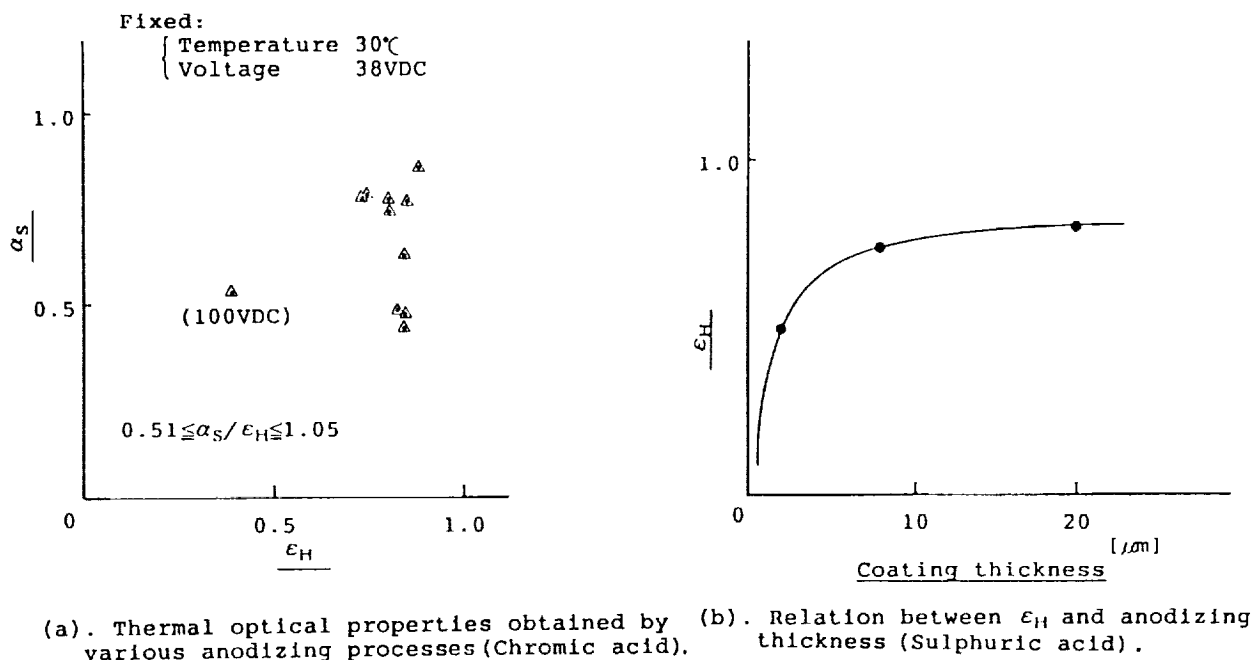


Figure 3. Thermal optical properties of anodized coating.

GROWTH OF EROSION FROM COATING DEFECTS

The purpose of this experiment is to evaluate the growth of erosion which will start from the coating defects under LEO.

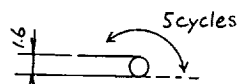
Indium-Tin-Oxide (ITO) or Silicon-dioxide (SiO_2) coated polymeric materials are known to be unaffected by atomic oxygen and can be applicable to JEM. Since ITO or SiO_2 is essentially brittle, however, some defects (like micro cracks) can be a starting point of erosion that cannot be avoided. Pin-holes by micro-meteoroids or debris, or perforations as air discharges, can also act in the same manner.

By knowing the quantity of the development of defects and why they are caused, these coatings can be applicable occasionally to JEM or Space Station Freedom— that is, for example, in limitation of duration of usage or in application suffering fewer AO/UV fluxes.

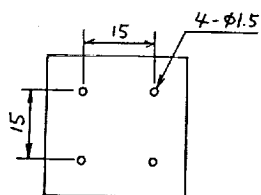
Three types of defects introduced in this experiment are shown in Figure 4, along with their sources.

(1) Microcracks

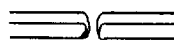
5 cycles bending of 180° against 1.6 mm diameter mandrel.



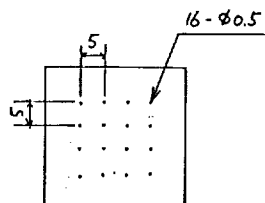
(2) Air holes



Perforation should precede coating



(3) Pin holes



Pinholing is preceded by coating



Figure 4. Making of "defects".

COMPARISON OF DAMAGE AMONG DIFFERENT DIRECTION ARRANGEMENTS OF GRAPHITE CRYSTALS

The purpose of this experiment is to compare damages among different direction arrangements of graphite crystals in carbon fibers.

In the process of calcining carbon fibers, temperature influences the direction arrangements of carbon graphite crystals. The highly developed and closed-packed structure of hexagon is very stable chemically. This means there can be some differences of durability in LEO among graphite crystals which have different direction arrangements. In this experiment, two different direction arrangements of graphite crystals, such as radial and quasi-onion, are to be exposed to space (see Figure 5).

In evaluation of damage of post-retrieval samples, these methods as written below, will be used.

- (1) Evaluate the reaction rate by means of measuring "mass loss".
- (2) Observe the differences in erosion by inspecting the surface and/or section by SEM or TEM.
- (3) Investigate the change of the crystal size and of the direction arrangements by means of x-ray diffraction.

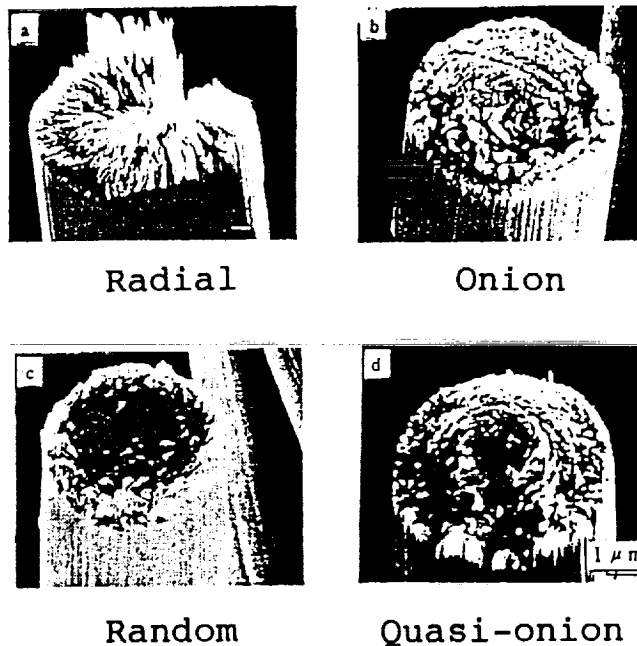


Figure 5. Coal-pitch carbon fibers (processed at 2500°C).

EFFECTS OF UV, AO AND THEIR SYNERGISM ON DIFFERENT TYPES OF FLUOROCARBON

The purpose of this experiment is to evaluate the effects of UV, AO and their synergism on Teflon films (i.e. FEP, TFE and ETFE) that have different chemical compositions.

FEP, TFE and ETFE are fluorocarbons (Teflon) which have respective chemical compositions (See Table II).

Teflon is well known for its anti-UV characteristics and this can easily be confirmed in the ground simulation testing.

Regarding anti-AO characteristics, Teflon has been said to be strong because of space shuttle experiments and many ground testings, but the Teflon samples retrieved from SMRM are damaged, differing from the preceding results. In SMRM, synergism of AO and UV was investigated only qualitatively (ref. 1). Teflon used in this experiment was not pure fluorocarbon "TFE", but a copolymer of -CH₂- and -CF₂- (they are equivalent to ETFE). On the other hand TFEs are composed only of strong -CF₂- bondings and have no weak -CH₂- bonding. At this point TFEs can be expected to be stable satisfactorily in the LEO environment.

Table II. Chemical Composition of Teflons

Name	PTFE	PFA	FEP	ETFE
	<u>Polytetrafluoroethylene</u>	<u>Perfluoroalkoxy</u>	<u>Fluorinated Ethylene Propylene</u>	<u>Ethylene Tetrafluoroethylene</u>
Chemical Composition	$\left[\begin{array}{cc} \text{F} & \text{F} \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{F} & \text{F} \end{array} \right]_n$	$\begin{array}{ccccccc} \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} & \text{F} \\ & & & & & & \\ -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & - \\ & & & & & & \\ \text{F} & \text{F} & \text{F} & \text{O} & \text{F} & \text{F} & \\ & & & \text{Rf} & & & \end{array}$	$\left[\left(\begin{array}{cc} \text{F} & \text{F} \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{F} & \text{F} \end{array} \right)_x \begin{array}{cc} \text{F} & \text{CF}_3 \\ & \\ -\text{C} & -\text{C}- \\ & \\ \text{F} & \text{F} \end{array} \right]_n$	$\left[\begin{array}{cccc} \text{H} & \text{H} & \text{F} & \text{F} \\ & & & \\ -\text{C} & -\text{C} & -\text{C} & -\text{C}- \\ & & & \\ \text{H} & \text{H} & \text{F} & \text{F} \end{array} \right]_n$

Reference

1. R. H. Liang, K. L. Oda, S. Y. Chung and A. Gupta: 18th International SAMPE Technical Conference, Oct. 7-9, 1986.

SFU ORBIT ENVIRONMENT MONITORING BY KAPTON

The purpose of this experiment is to acquire transient variation of irradiation fluence of AO in the flight orbit of SFU.

Parilene (Poliparaxylylene) coated Kapton specimens are used. This coating is vapor deposited and processed to one side. Parilene can easily be controlled through its coating thickness—almost to the accuracy of $0.1 \mu\text{m}$. Being exposed to space, the Parilene layer of the sample is eroded at first by AO; the Kapton layer of the base appears in some months.

By preparing Parilene layer specimens of different thicknesses, we can precisely control the period of exposure time of Kapton (See Figure 6).

After the retrieval, examining the quantity of the surface erosion, (loss of thickness): $\Delta t[\text{cm}]$, we can get such plotting as shown in Figure 7(a). Linearity of the erosion of Kapton with AO fluence is already confirmed in the LDEF experiment, so we first confirm this linearity again and then finally get the AO fluence characteristics shown in Figure 7(b).

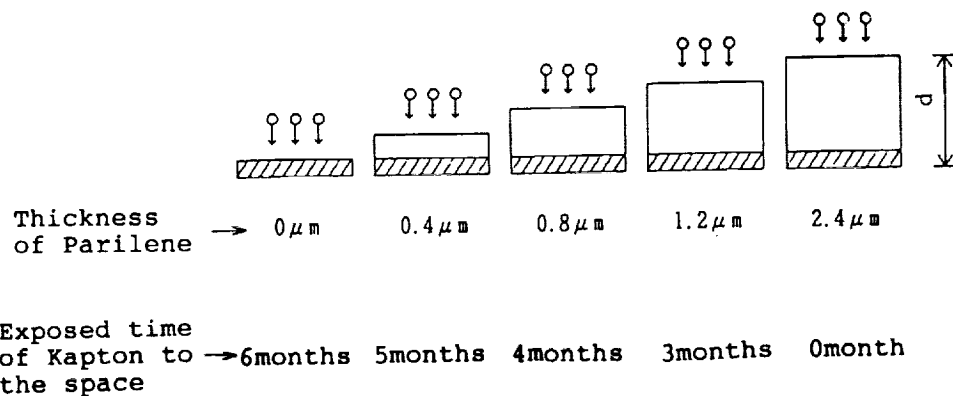
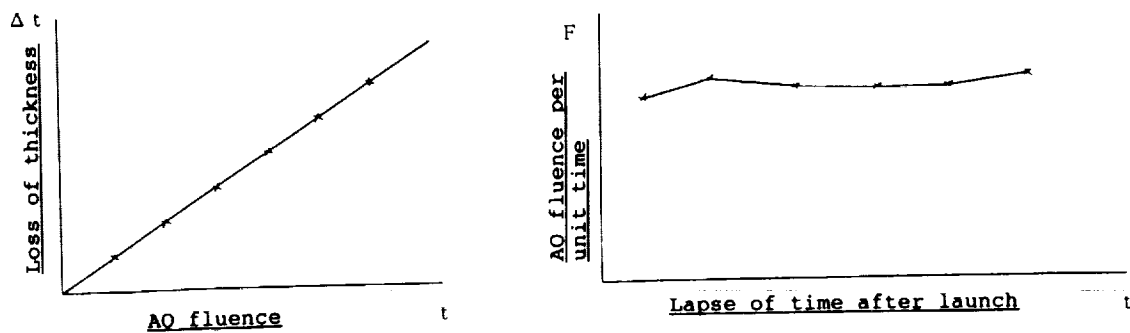


Figure 6. Mechanism of environment monitor.



(a) Erosion vs. period.

(b) AO fluence vs. elapsed time.

Figure 7. Expected plottings.

EXPECTED RESULTS AND SCHEDULE

Expected results brought from the experiment are summed up as follows:

1. After estimating declination quantity of each material during 10 years in LEO, we can confirm adaptability of those materials to JEM.
2. Confirmation and investigation can be achieved about the validity of ground simulation test equipment of AO irradiation.*
3. Base data for future development of space materials can be obtained (reaction data, etc.).

Schedule of this experiment is shown in Figure 8. Ground testing beforehand is very important because the number of the flight samples is limited. To reflect the results of this experiment in JEM's design, the schedule is very tight. JEM's system fabrication is to start in 1995.

The authors wish to express their sincerest appreciation to the session chairmen, workshop coordinators and the LDEF Chief Scientist for getting the chance to present this paper. To do this experiment successfully, advice, comments, and questions are very helpful and almost indispensable.

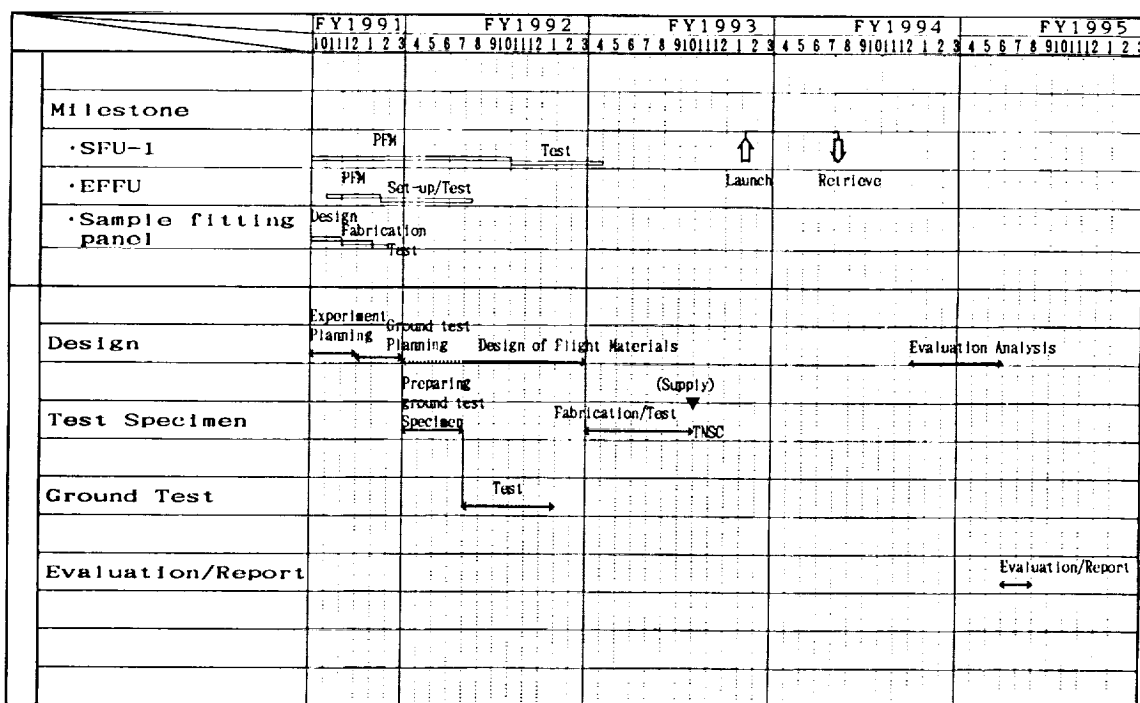


Figure 8. Schedule of the experiment

*IHI has developed its own equipment.

